Ontario Geological Survey
Aggregate Resources Inventory
Paper 50

Aggregate Resources Inventory of the Regional Municipality of Hamilton-Wentworth Southern Ontario

By Staff of the Engineering and
Terrain Geology Section
Ontario Geological Survey

1984

Ontario
Ministry of Natural Resources
Hon. Alan W. Pope
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John R. Sloan
Deputy Minister

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ISSN 0708-2061
ISBN 0-7743-5228-0

This report was prepared by: Staff of the Aggregate Assessment Office, Engineering and Terrain Geology Section of the Ontario Geological Survey, Ontario Ministry of Natural Resources, 77 Grenville Street, Toronto, M5S 1B3, Telephone (416) 965-1182.

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The Mineral Resources Staff of Cambridge District, Central Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

Parts of this publication may be quoted if credit is given to the Ontario Ministry of Natural Resources, Ontario Geological Survey. It is recommended that reference to this report be made in the following form:

Ontario Geological Survey
1984: Aggregate Resources Inventory of the Regional Municipality of Hamilton-Wentworth; Ontario Geological Survey, Aggregate Resources Inventory Paper 50, 53 p., 6 tables, 6 maps, scale 1:50 000.

Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

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CONTENTS

Page

Abstract v
Introduction 1
Part I - Inventory Methods 2
Field and Office Methods 2
Resource Tonnage Calculation Techniques 2
Sand and Gravel Resources 2
Bedrock Resources 3
Units and Definitions 3
Part II - Data Presentation and Interpretation 4
Map 1 Distribution of Sand and Gravel Deposits 4
Map 2 Selected Sand and Gravel Resource Areas 4
Site Specific Criteria 5
Deposit Size 5
Aggregate Quality 5
Location and Setting 6
Regional Considerations 6
Map 3 Bedrock Resources 7
Selection Criteria 7
Selected Resource Areas 7
Part III - Assessment of Aggregate Resources in the Regional Municipality of Hamilton-Wentworth 9
Location and Population 9
Physiography and Surficial Geology 9
Extractive Activity for Sand and Gravel in the Regional Muncipality of Hamilton-Wentworth 13
Selected Sand and Gravel Resource 13
Selected Sand and Gravel Resource Areas in the Township of Flamborough and the Town of Ancaster 14
Selected Sand and Gravel Resource Area 1 14
Selected Sand and Gravel Resource Area 2 14
Selected Sand and Gravel Resource Area 3 15
Selected Sand and Gravel Resource Area 4 15
Sand and Gravel Resource Areas of Secondary Significance 15
Selected Sand and Gravel Resource Areas in the Town of Stoney Creek and Township of Glanbrook 16
Bedrock Geology 16
Extractive Activity for Crushed Stone in the Regional Municipality of Hamilton-Wentworth 20
Selected Bedrock Resource Areas in the Township of Flamborough 20
Selected Bedrock Resource Area 1 20
Selected Bedrock Resource Area 2 21
Selected Bedrock Resource Area 3 21
Selected Bedrock Resource Area 4 22
Selected Bedrock Resource Areas in the Town of Ancaster 23
Selected Bedrock Resource Areas in the Town of Stoney Creek 23
Selected Bedrock Resource Area 5 23
Selected Bedrock Resource Areas in the Township of Glanbrook 23
Selected Bedrock Resource Area 6 23
Selected Bedrock Resource Area 7 24
Summary 24
References 41
Appendix A - Suggested Additional Reading 43
Appendix B - Glossary 44
Appendix C - Geology of Sand and Gravel Deposits 42
Appendix D - Geology of Bedrock Deposits 50

TABLES

1 - Total Sand and Gravel Resources, Regional Municipality of Hamilton-Wentworth . . 26
2 - Sand and Gravel Pits, Regional Municipality of Hamilton-Wentworth 28
3 - Selected Sand and Gravel Resource Areas, Regional Municipality of Hamilton-Wentworth 31
4 - Total Identified Bedrock Resources, Regional Municipality of Hamilton-Wentworth 32
5 - Quarries, Regional Municipality of Hamilton-Wentworth 37
6 - Selected Bedrock Resource Areas, Regional Municipality of Hamilton-Wentworth . 39

FIGURES

1 - Key Map Showing Location of the Regional Municipality of Hamilton-Wentworth . v
2 - Physiographic Regions in the Regional Municipality of Hamilton-Wentworth 11
3 - Stratigraphy of the Niagara Escarpment 17
4 - Bedrock Geology of Southern Ontario 50

MAPS
(back pocket)

1 (West) - Distribution of Sand and Gravel Deposits, Regional Municipality of Hamilton-Wentworth (West Half), Scale 1:50 000.
1 (East) - Distribution of Sand and Gravel Deposits, Regional Municipality of Hamilton-Wentworth (East Half), Scale 1:50 000.
2 (West) - Selected Sand and Gravel Resource Areas, Regional Municipality of Hamilton-Wentworth (West Half), Scale 1:50 000.
2 (East) - Selected Sand and Gravel Resource Areas, Regional Municipality of Hamilton-Wentworth (East Half), Scale 1:50 000.
3 (West) - Bedrock Resources, Regional Municipality of Hamilton-Wentworth (West Half), Scale 1:50 000.
3 (East) - Bedrock Resources, Regional Municipality of Hamilton-Wentworth (East Half), Scale 1:50 000.

ABSTRACT

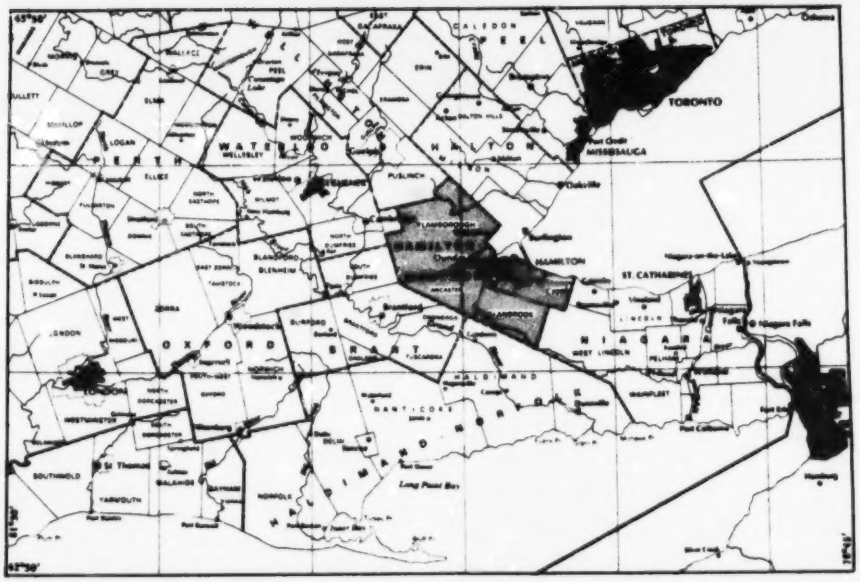

Figure 1 - Key Map Showing the Location of the Regional Municipality of Hamilton-Wentworth, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in the Regional Municipality of Hamilton-Wentworth. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971.

In the regional municipality, four areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Resource Areas occupy 5600 acres (2270 ha), exclusive of licenced areas. An estimated 3400 acres (1380 ha) are currently available for extraction, containing possible resources of 130 million tons (118 million tonnes). The available portions of the selected areas make up 5 percent of the total area occupied by sand and gravel deposits in the region and represent 5 percent of the total resource tonnage.

Selected Sand and Gravel Resource Area 1 is an outwash deposit located in the northern part of the Township of Flamborough. Area 1 forms the most important natural aggregate deposit in the township and contains an estimated 38 million tons (34 million tonnes) of sand and gravel.

Selected Resource Area 2 in the Township of Flamborough contains ice-contact stratified drift and esker deposits which contain combined possible resources of 68 million tons (62 million tonnes). Resource Area 3 is a smaller outwash deposit at the eastern boundary of the Township of Flamborough and contains possible resources of 18 million tons (16 million tonnes).

One area has been selected for resource protection in the Town of Ancaster. This area is composed of several outwash deposits and has possible resources of 6 million tons (5 million tonnes). In addition to the Primary Resource Areas, several large lacustrine deposits in the Township of Flamborough and the Town of Ancaster have been selected as Resource Areas of Secondary Significance. These deposits contain large amounts of low-specification aggregate such as granular fill, but have only limited amounts of crushable gravel.

Very large possible resources of crushed stone are available throughout the regional municipality and the areas selected for possible resource protection represent a resource of provincial significance. Stone from the Lockport and Amabel Formations is well suited for production of high quality road-building and construction aggregate. Several areas of these formations have been selected and total possible resources are 7800 million tons (7100 million tonnes). Most of the resource tonnage is located in the Township of Flamborough. Stone from the Guelph Formation is not well suited for production of load-bearing aggregate but is a valuable raw material for chemical and metallurgical products. Several areas containing the Guelph Formation have been selected for possible resource protection. These selected areas have resources of 6900 million tons (6300 million tonnes).

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF THE REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief Engineering and Terrain Geology Section, May 11, 1983.
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PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Wherever possible, field examination of potential resource areas was also undertaken to confirm interpretations made in the office. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-size fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Air photos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

In the office, the pit data were supplemented by information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows: First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot thick layer of sand and gravel, one acre in extent, assuming an average density of 110 pounds per cubic foot.

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2).

Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas lying outside of licenced properties that have previously been extracted (e.g. wayside pits are included in this cateogry). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favourable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot thick section of dolostone, one acre in extent, assuming a bulk density of 165 pounds per cubic foot).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot or approximately 3200 tons per acre. Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompny the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p. 7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

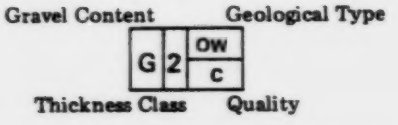
PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived directly from the existing surficial geology maps of the area or from air photo interpretation where surficial mapping is incomplete. It shows the extent of sand and gravel deposits within the study area and serves as a base for the calculation of the total sand and gravel resources.

Map 1 presents a summary of all available information related to the quantity and quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbol which identifies each deposit. The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit as discussed in the next section.

The other information presented on Map 1 is designed to give an indication of the present level of extractive activity in the study area. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a medium-grey tone on Map 2.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light grey tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no grey tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extraction development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent crushable gravel are considered to be favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Exesss "fines" or high silt and clay content may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fine content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" particles (those greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building

aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is "lithology". Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C" "O" or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but readers are encouraged to discuss them with personnel of the Ontario Ministry of Natural Resources' District Office.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological

data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical well data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the labelled bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three tones. The darkest tone indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance due to their easy access. The medium tone indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest tone indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and use of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Three factors support this approach. Quality and quantity variations are gradual. The areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material. Since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wider range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN THE REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

LOCATION AND POPULATION

The Regional Municipality of Hamilton-Wentworth occupies an area of 275,021 acres (111 301 ha) at the western end of Lake Ontario, as shown on Figure 1. Detailed map coverage of the regional municipality is provided on portions of the Hamilton-Burlington (30M/5), Hamilton-Grimsby (30 M/4), Cambridge (40P/8), and Brantford (40P/1) map sheets of the National Topographic System, at a scale of 1:50 000.

The Regional Municipality of Hamilton-Wentworth was created by provincial statute in 1974 from Wentworth County and new Area Municipalities were organized. The geographic townships of Beverly, East Flamborough and West Flamborough were amalgamated to form the Township of Flamborough and the geographic townships of Glanford and Binbrook were combined to form the Township of Glanbrook. The geographic township of Ancaster was divided to form the Town of Ancaster and the Town of Dundas; the geographic township of Saltfleet was renamed the Town of Stoney Creek, and Barton Township became the City of Hamilton. The present boundaries of the new Area Municipalities are shown on Figure 2. The inventory and selection maps which accompany the report combine the Town of Ancaster and the Township of Flamborough on one sheet and the remainder of the regional municipality on a second sheet. Although the Town of Dundas and the City of Hamilton have been included in these base maps, no inventory or selection information has been indicated within their boundaries. It is felt that competing land uses in these municipalities would prohibit extractive activity.

The City of Hamilton is the largest urban area in the regional municipality. In 1982 the city had a population of 308 102 (Ontario Ministry of Municipal Affairs and Housing 1983). At a projected annual growth rate of less than 1 percent, the population of the city is expected to reach approximately 386 000 by the year 2001 (Regional Municipality of Hamilton-Wentworth 1980). A much larger growth rate is projected for the Town of Stoney Creek, which is the second largest urbanized area in the regional municipality. A 6 percent growth rate, leading to a population of 75 000 by the year 2001, is projected for this area. Other population centres are Dundas, Waterdown and Ancaster. The townships of Glanbrook and Flamborough are predominantly rural and have relatively lower population concentrations and projected growth rates. For the region as a whole, an annual growth rate of 1.5 percent, and a projected population of 550 000 by the year 2001 have been estimated in the Official Plan (Regional Municipality of Hamilton-Wentworth 1980). Approximately 17,000 acres (6900 ha) of land will be required to accomodate the projected population increases and large amounts of natural and crushed stone aggregate will be required for industrial, residential and road construction. In conjunction with greater aggregate demand, increasing land use competition will likely result in more sterilization of the already limited natural aggregate resources in the region. Fortunately the region has very large possible resources of crushed bedrock aggregate which constitute a resource of provincial significance.

The region is strategically located along the transport corridor between southern Ontario, the Niagara Peninsula and the United States. The narrow plain flanking the lake below the Niagara Escarpment is the focus for the Queen Elizabeth Way, a multilane highway, as well as several other King's Highways. Rail lines of the Canadian National and Canadian Pacific Railways and the Toronto, Hamilton and Buffalo Railway are also located on this plain. The southern and western portions of the regional municipality are served by at least ten King's Highways and several rail lines. On a local level, most of the regional municipality is served by a well developed grid of paved regional and gravel-surfaced local roads. Access is least well developed in the sparsely populated Flamborough Plain in the western part of the regional municipality (Figure 2), where there is a limited road network and no direct rail access.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography of the Regional Munici-

pality of Hamilton-Wentworth reflects the form of the bedrock which underlies the land surface. The Niagara Escarpment, which forms a scarp or cliff inland from and roughly parallel to the Lake Ontario shoreline, is the most prominent physiographic feature. It divides the regional municipality into two broad zones. Below, or to the east of the Escarpment, Ordovician age shales are overlain in places by glacial till or by a veneer of lacustrine sediments deposited in glacial Lake Iroquois. This area forms part of the Iroquois Plain physiographic region (Chapman and Putnam 1966, p.324) which is shown on Figure 2.

Above or to the west of the Escarpment brow, Silurian age limestones and dolostones are thinly covered by a variety of glacial deposits including glacial till, and sand, silt and clay which were laid down in several glacial lakes which occupied the area at various times. This area can be divided into three physiographic regions, as shown on Figure 2. The Flamborough Plain (Chapman and Putnam 1966, p. 203) occupies the northern part of the Township of Flamborough and consists of a veneer of glacial till and scattered drumlins deposited on the flat bedrock surface. Extensive wetlands like the Beverly Swamp have formed in poorly drained areas on the till plain. The headwaters of several streams which drain toward Lake Ontario are also found on the plain.

The Norfolk Sand Plain (Chapman and Putnam 1966, p. 251) occupies the central portion of the regional municipality, including the southern part of the Township of Flamborough and the northern part of the Town of Ancaster. Gently undulating deltaic sands predominate although outwash and morainic deposits are found in the east, near Carlisle.

The southern part of the region, including most of the Town of Stoney Creek and the Township of Glanbrook, forms part of the Haldimand Clay Plain (Chapman and Putnam 1966, p. 255). The plain consists of a thin layer of fine-grained lacustrine sediments deposited on the bedrock surface. Two large, east-west trending moraines interrupt the predominantly level land surface just south of the brow of the Niagara Escarpment.

A better understanding of the type and distribution of the surficial materials in the various physiographic regions may be gained from a brief summary of the glacial history of the area. The glacial activity responsible for the present distribution of sediments (including the sand and gravel deposits shown on Maps 1 and 2) occurred during the Late Wisconsinan Substage of the Pleistocene Epoch. This period of time, which lasted from approximately 23 000 to 10 000 years before the present, was marked by the repeated advance and melting of extensive, continental ice sheets. The regional municipality was covered several times during the Late Wisconsinan by an ice mass that moved out of the Lake Ontario basin.

The surficial materials that are found in the region have been mapped and reported on by several authors. The northern half of the region has been mapped by Karrow (1963; 1983) and the southwestern and southeastern parts were mapped respectively by Cowan (1972) and Feenstra (1975). The evaluation of sand and gravel in the region is based for the most part on their work.

A major advance of the Ontario ice lobe occurred during the Late Wisconsinan (Port Bruce Stadial, Barnett 1979). Part of the ice mass advanced northwest across the Township of Flamborough, depositing an extensive drumlinized till plain composed of Wentworth Till (Karrow 1963). A halt in the retreat of the margin after this advance is marked by the Galt Moraine, a large irregular ridge largely composed of Wentworth Till, located at the northwestern corner of the Township of Flamborough (Karrow 1963). Wentworth Till is generally sandy often stony (Cowan 1972). For the most part it is unsuitable for use as aggregate because of poor sorting and high clay and silt content.

In response to a climatic change at the end of the Port Bruce Stadial, the margins of the Ontario ice lobe retreated below the Niagara Escarpment (Cowan 1972; Karrow 1963). At the beginning of the last cold period in the Late Wisconsinan (Port Huron Stadial, Barnett 1979) the Ontario lobe margin again advanced northwest. In the north, the position of the ice margin is marked by the Waterdown Moraines located on the Escarpment brow near Waterdown. In the south the ice advanced as far as Caledonia before retreat. The Niagara Falls and the Vinemount moraines, which are located south of the Escarpment brow in the Town of Stoney Creek, mark successive retreat positions of the ice (Feenstra 1975). All of these moraines are

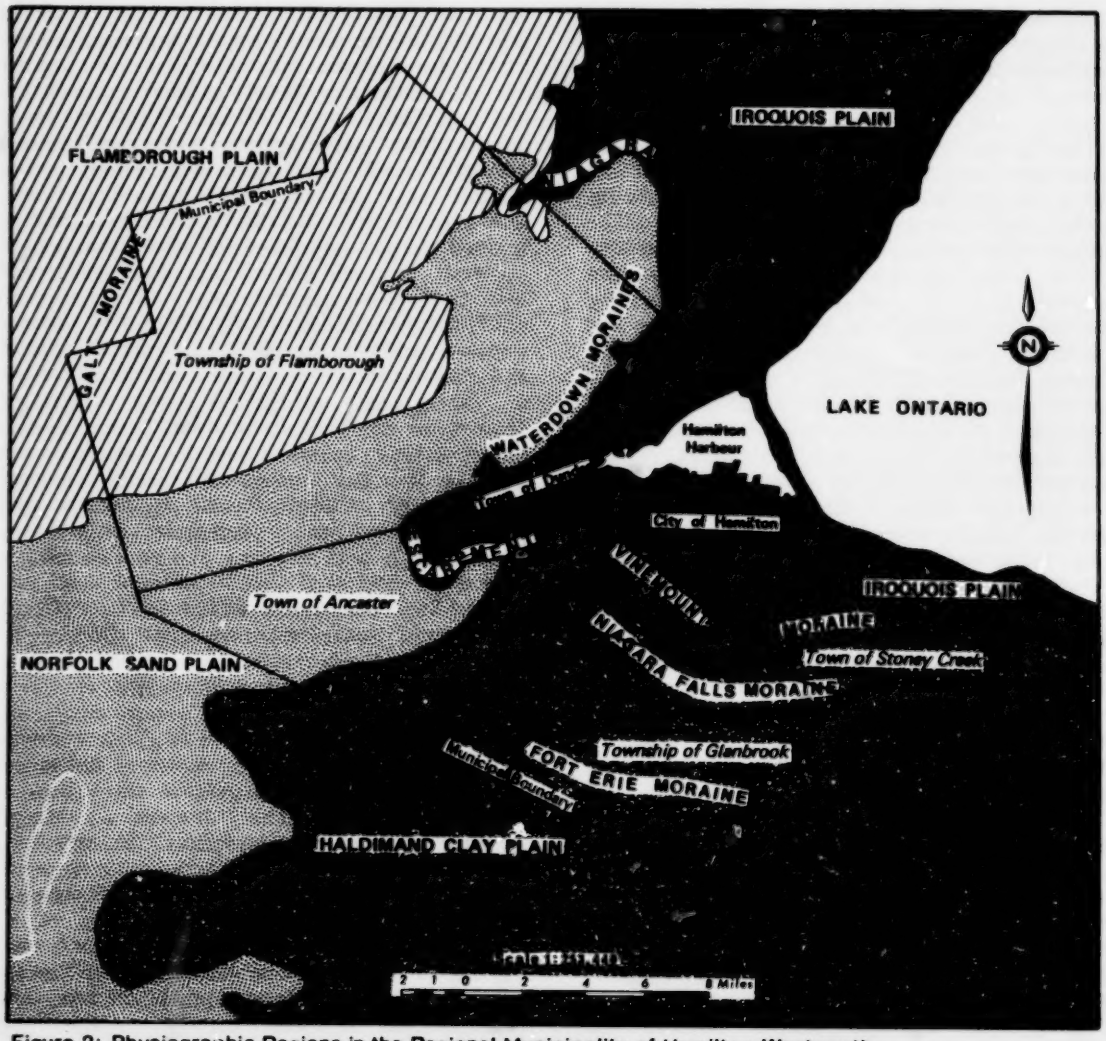


Figure 2: Physiographic Regions in the Regional Municipality of Hamilton–Wentworth, after Chapman & Putnam, 1966.

composed of Halton Till a silty, relatively stone-free till (Cowan 1972, p. 17) which, like the Wentworth Till, has no value as an aggregate source.

During the Port Huron advance glacial meltwater was dammed between the ice margin and higher ground to the west and south, forming glacial Lake Whittlesey (Barnett 1979). The lake covered most of the regional municipality at one time, and greatly affected the present distribution of unconsolidated sediments in the area. In the north, the Flamborough Plain was inundated and, in places, wave action completely removed the till from the bedrock surface and notched the flanks of drumlins to form small beach deposits. A number of small pits opened in these beach deposits expose aggregate which is generally dirty, poorly sorted and contains stone of poor quality. Potential uses for this aggregate are thus limited, although it has been used locally for fill, granular borrow and some road sub-base aggregate (Fraser 1974). The pits in these deposits are nearly all depleted and long abandoned and remaining resources of similar aggregate are very small.

Deltaic and shallow water lacustrine sand deposits cover much of the central portion of the regional municipality and form the Norfolk Sand Plain. The material was carried south into glacial Lake Whittlesey by meltwater channels which were located between the ice margin and the Escarpment. Water well data indicate that the sand may have a depth of greater than 100 feet (30 m) in places, but generally is 20 to 30 feet (6 to 9 m) thick. Several pits have been opened in these deposits, all of which have been inactive for a long period. The pits are developed in fine sand so that products have been restricted to Granular Base Course C. The quality of the material is poor; the sand is fine grained and silty, and in places is naturally cemented. Although sand and gravel from these deposits are of limited use they represent large reserves of fine-grained aggregate.

Deeper water lacustrine silt and clay cover most of the southern portions of the regional municipality and form the Haldimand Clay Plain. In most cases it is not possible to distinguish the Lake Whittlesey deposits from those of later, lower-level glacial lakes (Cowan 1972). The deposits consist of laminated to varved silt, clay, and minor sand and vary in thickness from a thin veneer on the bedrock surface in the northern part of the region to more than 120 feet (37 m) in the Town of Ancaster (Cowan 1972). In places the silt and clay may be suitable for structural clay products such as brick and drainage tile (Cowan 1972, p. 48), as evidenced by an abandoned clay pit in the southwestern corner of the Township of Flamborough.

While the margin of the Ontario lobe remained near the brow of the Escarpment, outwash and ice-contact stratified drift were deposited in the northern part of the Township of Flamborough (Karrow 1963). The outwash deposits grade to the southwest into the deltaic and shallow water lacustrine deposits laid down at the margin of glacial Lake Whittlesey. Numerous pits (some of which are presently licenced for extraction) have been developed in outwash deposits located at Harper Corner and Flamborough Station. These deposits contain predominantly sandy aggregate suitable for crushing only with selection and sand control.

West of the small valley in the Niagara Escarpment near Flamborough Station, a fragment of the ice lobe became anchored and melted in place, depositing a large body of kame sand and gravel and several associated esker segments (Karrow 1963). Together with the outwash these deposits represent the largest sources of natural aggregate in the entire regional municipality. The kame deposits consist of poorly sorted sand and silt. The material is generally suited for road subgrade aggregate but is not suitable for concrete or road-surfacing aggregate because of excess silt and clay content and poor stone quality. Several pits have been developed in the esker deposits at Freelton and north of Carlisle. These deposits contain small resources of crushable aggregate suitable for road-building products.

As the climate warmed near the end of the Port Huron Stadial, the margin of the Ontario ice lobe melted back from the Niagara Escarpment into the Lake Ontario basin. This resulted in a succession of lower level glacial lakes of which Lake Iroquois is of greatest importance.

The Lake Iroquois shore was located below the base of the Niagara Escarpment throughout most of the region and prominent shore features such as beach bluffs, spits and bars resulted. Part of the City of Hamilton is built on the Aldershot bay mouth bar, a large gravel ridge which developed across part of Hamilton Harbour.

Foreshore sands deposited in shallow water near the Iroquois beach form a smooth gently sloping surface that characterizes the Iroquois Plain in this area. East of the City of Hamilton the Iroquois Plain consists of a relatively thin wave-washed layer of Halton Till overlying bedrock of the Queenston Formation. In the Town of Stoney Creek the Iroquois bluff is predominantly erosional and there is only one very small beach deposit located just west of Winona (Feenstra 1975).

EXTRACTIVE ACTIVITY FOR SAND AND GRAVEL IN THE REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

In the past, sand and gravel extraction has taken place primarily in the Township of Flamborough and the Town of Ancaster. Possible resources of natural aggregate are not significant in the rest of the regional municipality.

A large number of pits have been opened in the Township of Flamborough but many are very small and have been long abandoned, especially those developed in the extensive lacustrine plains. Twenty-one pits have been shown on Maps 1 and 2 for the Township of Flamborough and they are described in Table 2. The great majority of the pits are developed in the outwash and ice-contact stratified drift deposits in the north-central portion of the township. At the time of writing five pits were licenced for extraction under The Pits and Quarries Control Act, 1971.

At least five sand and gravel pits have been opened in lacustrine and associated small outwash deposits in the central portion of the Town of Ancaster. Three of these sources were licenced for extraction at the time of writing of this report (pit nos. 22, 23 and 24).

The total area occupied by the eight licenced sand and gravel pits in the Regional Municipality of Hamilton-Wentworth is 443.9 acres (179.6 ha). The tonnage of sand and gravel removed from the licenced sources has been tabulated on an annual basis by the Cambridge District Office of the Ministry of Natural Resources. Over the five-year period from 1976 to 1980 the average annual production was 408,000 tons (370 000 tonnes).

SELECTED SAND AND GRAVEL RESOURCES

Deposits of crushable gravel are found only in the Township of Flamborough and the Town of Ancaster. There are virtually no natural aggregate resources in the Town of Stoney Creek or the Township of Glanbrook. The nature and distribution of these deposits are shown on Map 1. Much of the material in the report area, especially the fine sand in the lacustrine deposits, will have low potential for use.

The sand and gravel deposits selected for possible resource protection in the Township of Flamborough and the Town of Ancaster are shown on Map 2 (West). Three deposits have been selected for possible resource protection at the primary level in the Township of Flamborough. They are the outwash and ice-contact stratified drift deposits in the north-eastern corner of the township. Presently available portions of the three areas occupy a total of 3300 acres (1340 ha) and have possible resources of 124 million tons (112 million tonnes). In the Town of Ancaster, the lacustrine sand and associated outwash deposits in the central portion of the town have been selected for possible resource protection. The outwash deposits have been selected at the primary level and have a total available area of 110 acres (44 ha) with possible resources of 6 million tons (5 million tonnes). The fine-grained lacustrine deposits have been selected at the secondary level.

The Selected Sand and Gravel Resource Areas of Primary Significance in Hamilton-Wentworth occupy a total of 3400 acres (1380 ha) with an estimated tonnage of 130 million tons (118 million tonnes). This represents 5 percent of the total area occupied by sand and gravel deposits in the Regional Municipality of Hamilton-Wentworth, and 5 percent of the region's total possible resource tonnage. These deposits contain virtually all of the possible resources of crushable gravel in the region.

In addition to the areas selected at the primary level of significance, the large lacustrine sand deposits in the Township of Flamborough and the Town of Ancaster have been selected for possible resource protection at the secondary level. Although these deposits do not contain appreciable amounts of crushable aggregate they do contain very large possible resources of sand suitable for some road-building and construction

uses. Because of their extensive nature, they provide convenient sites for local, small-scale extractive development.

SELECTED SAND AND GRAVEL RESOURCE AREAS IN THE TOWNSHIP OF FLAMBOROUGH AND THE TOWN OF ANCASTER

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is an extensive outwash deposit located in the central part of the township, west of Harper Corner. The deposit consists of a level plain which was deposited on top of the underlying drumlinized till plain. A drumlin can be seen surrounded by the outwash deposit in the central part of the Area. The outwash material was deposited in a fluvio-deltaic environment during the advance of the Ontario ice lobe that deposited the Halton Till. A number of pits have been opened in the Resource Area, two of which (pit nos. 1 and 5) are presently licenced for extraction. Faces in the pits range in height from 10 to 15 feet (3 to 5 m) and expose generally very sandy, moderately sorted and stratified outwash. Field investigation has shown that crushable gravel content is quite low. In most areas careful selection (ie. selection of the coarsest parts of the pit face for extraction) and sand control are required, although moderate amounts of road base course aggregate have been produced in the past. The sand fraction of the aggregate grades coarse for hot-laid asphaltic products and often contains a large proportion of silt. A high water table in parts of the Resource Area may limit the accessibility of some of the aggregate. Draglines are presently in operation in some of the pits.

Selected Sand and Gravel Resource Area 1 occupies a total of 1490 acres (600 ha), exclusive of licenced areas. Much of the eastern portion of the Resource Area is now unavailable for extraction because of residential development at Harper Corner, however, and it is estimated that 1020 acres (415 ha) of the Resource Area are presently available for possible extraction. Assuming an average thickness of usable material of 15 feet (5 m) throughout the Resource Area, presently available sand and gravel resources are estimated to be 38 million tons (34 million tonnes). Most of the available material is located in close proximity to the existing pits. Access to the Resource Area is provided by several paved and gravel-surfaced roads and the deposit is well situated with respect to local demand centres.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is a very large ice-contact stratified drift deposit located in the north-central part of the township, between Strabane and Carlisle. The land surface in the Resource Area is irregular and hummocky, in contrast to the level topography of the outwash deposit making up Resource Area 1 to the south. As in Resource Area 1, the ice-contact stratified drift was deposited over the pre-existing drumlinized till plain during the 'Halton' advance of the Ontario ice lobe. A large drumlin protrudes through the ice-contact stratified drift just to the east of Strabane. Several well defined esker deposits are found along the northern flank of Resource Area 2. Parts of these eskers have been included in the Area.

Because of the ice-contact nature of the deposit, the material will be irregular and concentrations of gravel will be found only locally. Generally, this deposit is sandy. Water wells scattered throughout the Resource Area indicate approximately 20 to 40 feet of sand and gravel although several records in the eastern part of the Area indicate considerably thicker sequences of aggregate. No licenced pits have been opened in Area 2. A tested property at pit no. 14 provides the only detailed subsurface and textural information for the deposit. Test holes made by the Ontario Ministry of Transportation and Communications in this area indicate 20 to 25 feet (6 to 8 m) of aggregate, 30 to 40 percent of which is gravel. The aggregate is considered to be acceptable for the production of Granular Base Course A and B but unacceptable for hot-laid asphaltic aggregate because of poor stone quality and excess silt and clay. Further investigation of different parts of the Resource Area would be required to assess, more accurately, the overall quality of the aggregate. It is probable, however that possible resources of aggregate suitable for some crushed products are available.

Selected Resource Area 2 has a total of 3450 acres (1400 ha). However, significant portions of the Area are now unavailable at the fringes of Strabane and Carlisle, and along the roads that traverse the deposit. It is estimated 1800 acres (730 ha) in Area 2 are presently available for

extraction. Assuming an average thickness of usable material of 15 feet (5 m) throughout the deposit, presently available sand and gravel resources are estimated to be 68 million tons (62 million tonnes). The Resource Area is accessible by road and is located in proximity to local market areas.

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 is an outwash deposit located at the eastern boundary of the township near Progreston. The deposit is the western extension of an outwash deposit selected for possible resource protection in the City of Burlington, Regional Municipality of Halton (Ontario Geological Survey 1982). The outwash was deposited by glacial meltwater at the edge of the Niagara Escarpment south of Kilbride. A small licenced pit (pit no. 3) has been opened in this deposit. Faces in the pit are 5 to 15 feet (2 to 5 m) high and expose material with a 35 percent gravel content. A licenced pit is also opened in the portion of this Resource Area in the City of Burlington. A 40- foot (12-m) face in that pit exposes sandy aggregate that has been used for asphaltic sand and some crushed products.

Bedrock is found near the surface in the central part of the Resource Area, indicating that the deposit is quite thin in places. For resource calculations, an average thickness of 15 feet (5 m) throughout the Area has been used. Area 3 occupies 530 acres (214 ha), exclusive of licenced areas, of which 490 acres (198 ha) are available for extraction. Possible resources of sand and gravel are estimated to be 18 million tons (16 million tonnes). Together with the portion of the deposit in the City of Burlington, Resource Area 3 provides a useful local site for the extraction of low-specification aggregate products, such as Granular Base Course C and fill. Road access to the Resource Area is good and the material is located in proximity to local market areas.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Resource Area 4 is made up of several outwash deposits located west of Ancaster. Licenced pit no. 22 is developed in one of the outwash bodies. Faces in this pit range from 15 to 20 feet (5 to 6 m) and expose well sorted sand with very little gravel. Siltstone is a common constituent of the gravel and this limits its possible uses. In places the aggregate is also cemented. An inactive source at pit no. 25 is also developed in a small outwash body. Gravel content in the pit is very low. A 7-foot (2-m) face in the pit exposes sandy aggregate which is suitable for Granular Base Course B and select subgrade aggregate, but as in pit 22, the aggregate is badly cemented in places, and is unusable. Sand and stone quality is considered unsuitable for some hot-laid asphaltic aggregate.

The mapped area of the outwash bodies that make up Resource Area 4 totals 140 acres (57 ha), of which 110 acres (44 ha) are presently available for extraction. Assuming an average thickness of usable material of 20 feet (6 m) throughout these deposits, possible resources of sand and some crushable gravel are estimated to be 6 million tons (5 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Parts of the very extensive deltaic and lacustrine sand deposits in the southern and eastern parts of the Township of Flamborough and the central part of Ancaster have been selected for possible resource protection at the secondary level. Although the probability of locating resources of crushable aggregate is low in these deposits and the material is suited only for low-specification aggregate products, they do contain large possible resources of material suitable for local road maintenance and for other needs, where proximity of the resource rather than material quality is of primary importance.

A portion of the lacustrine plain extending to the south from Carlisle and bounded by several Selected Resource Areas of Primary Significance, has been identified as a Resource Area of Secondary Significance. The Area was identified on the basis of numerous water well logs in the northern part of the deposit and on changes in topography at the southern boundary of the Resource Area. Several water wells at Carlisle indicate as much as 65 feet (20 m) of sand and gravel and it may be that the lacustrine fine sands found at surface in this area mask underlying coarse-grained deltaic and fluvial deposits. Detailed field investigation in this area may identify further resources of crushable aggregate.

The second major area selected for possible resource protection at the secondary level is the

lacustrine deltaic deposit that straddles the Flamborough-Ancaster boundary. Cowan (1972, p. 29) notes: "The area of sand in the Copetown-Lynden area resulted from sedimentation into glacial Lake Warren initially and then spread southwards as the waters receded . . . gravelly deposits have been described in conjunction with outwash deposits and the remainder of the deltaic material consists primarily of fine or very fine sand with some silt and in places silty fine sand." Water wells generally indicate 12 to 35 feet (4 to 11 m) of sand in most parts of the deposit. Cementation in parts of the deposit may also be a problem. A few wells show signficant amounts of silt and clay. Several pits have been developed in the Ancaster segment of the deposit (pit nos. 22, 23 and 24). These sources have generally shallow faces and expose sand only. The aggregate has been extracted for low-specification products such as fill and granular borrow.

Several small outwash deposits, located in the northeastern part of the township have been selected at the secondary level. No subsurface information is available for these deposits, but small possible resources of crushable gravel may be available for extraction. Because of the generally low possible resources of crushable material in the region it is important to protect as much of the available material as possible.

Three small esker segments in Flamborough have been selected at the secondary level. Much of the material in these esker deposits has already been extracted, but several small pockets of aggregate remain. It is probable that small amounts of crushable aggregate can be produced from the deposits.

SELECTED SAND AND GRAVEL RESOURCE AREAS IN THE TOWN OF STONEY CREEK AND THE TOWNSHIP OF GLANBROOK

The only aggregate deposits in the Town of Stoney Creek and Township of Glanbrook are very small lacustrine and postglacial alluvial deposits. These deposits are located below the Niagara Escarpment on the Iroquois Plain and in the valleys of Twenty Mile Creek and the Welland River, respectively. Possible resource tonnages for these deposits are given in Table 1. The aggregate in these deposits is not suited for road-building or construction aggregate, so the deposits have not been selected for possible resource protection.

BEDROCK GEOLOGY

The Regional Municipality of Hamilton-Wentworth is underlain by a succession of shale, sandstone, limestone and dolostone of Ordovician and Silurian age. The bedrock is covered by varying amounts of overburden but surface exposures are common on the Lake Iroquois Plain, along the face of the Niagara Escarpment and throughout the Flamborough and Haldimand plains. The bedrock formations trend northwest and have a gentle regional dip to the southwest. They occur in chronologic succession roughly from east to west. The location and distribution of the formations are shown on Map 3 (East and West) and their stratigraphic relationships are shown on Figure 3 (after Liberty, Bond and Telford 1976; Liberty, Feenstra and Telford 1976; and Telford 1979a, b).

The Niagara Escarpment is the dominant bedrock feature in the regional municipality. It forms a prominent cliff 2 to 3 miles (3 to 5 km) south of the shore of Lake Ontario in the Town of Stoney Creek and the City of Hamilton, then swings northward near Dundas, where the Escarpment is obscured by more than 200 feet (61 m) of drift. North of the Dundas valley the Escarpment face is again exposed and roughly parallels the southern boundary of the Township of Flamborough. The Escarpment leaves the region just east of Waterdown. The crest of the scarp is approximately 250 to 300 feet (76 to 91 m) high south of Lake Ontario, and its height increases north of Dundas.

The Queenston Formation is the oldest of the bedrock units in the regional municipality. The shale of this formation underlies the Iroquois Plain throughout the region and forms the base of the Niagara Escarpment. Its occurrence is often indicated by the characteristic brick-red colour of soils developed on the bedrock surface. The bedrock surface is level and overburden thickness is variable. West of the City of Hamilton, bedrock exposures are common since drift is relatively thin, consisting mainly of Halton Till. Within the city limits, the bedrock is covered by considerable amounts of till and lacustrine sediments. In the Dundas buried valley, drift reaches a depth of greater than 200 feet (61 m).

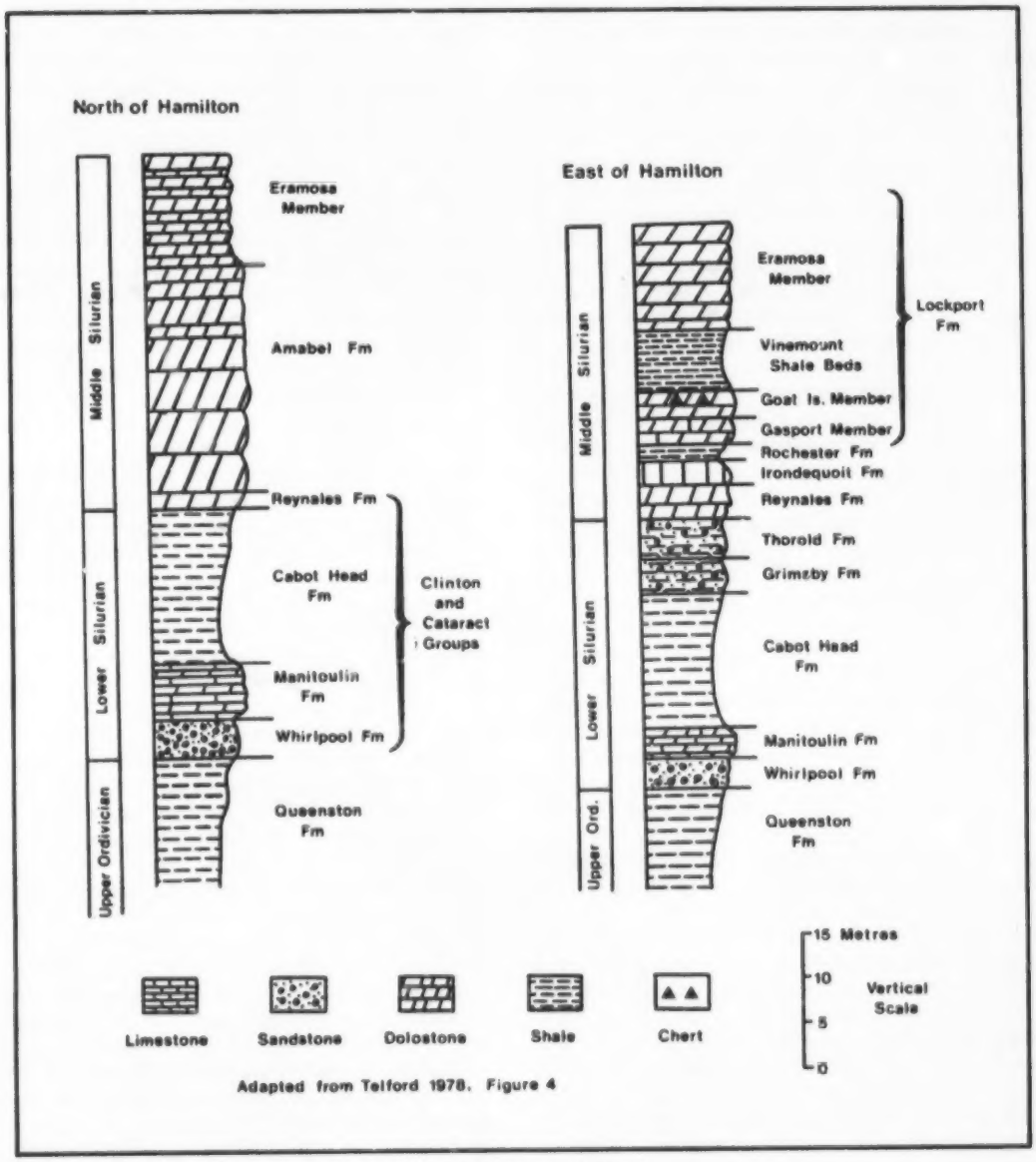


Figure 3: Stratigraphy of the Niagara Escarpment

The Queenston Formation consists of brick-red shale and mudstone with mottled green shale interbeds. It thins westward and has a thickness of approximately 700 feet (213 m) in the vicinity of Hamilton (Liberty, Feenstra and Telford 1976). The shale is well suited for the manufacture of structural clay products such as brick and tile and has been extensively extracted near Streetsville, Cooksville and Brampton (Guillet 1967). Two brick plants using the Queenston have been operated by the Canadian Pressed Brick Company and Hamilton Brick Limited in the City of Hamilton (Guillet 1967). A quarry has also been operated for many years by Natco Building Products at Aldershot, east of the Town of Dundas. Although the Queenston Formation is a resource of provincial significance for structural clay products, the shale is soft and easily eroded. As a result it is not suitable for the production of load-bearing aggregate for road building or construction.

Thin drift cover over the Queenston Formation in the northern part of the Town of Stoney Creek could make extraction feasible. Competing land use is severe in this area, however, and detailed planning would be required to select specific areas for possible extractive development. For this reason no selected areas have been identified in this report for possible resource protection.

The Queenston Formation is overlain by a succession of sandstone, shale, limestone and dolostone which make up the Clinton and Cataract Groups. These groups form much of the face of the Niagara Escarpment. Some of the constituent formations have been extracted elsewhere in southern Ontario for a variety of construction products, but little extraction has taken place within the Regional Municipality of Hamilton-Wentworth.

The Whirlpool Formation is the lowermost member of the Cataract Group and it unconformably overlies the Queenston Formation near the base of the Niagara Escarpment. It is not mapped separately on Map 3 because of its extremely limited extent. The Whirlpool Formation has a maximum thickness of only 10 to 15 feet (3 to 5 m) (Hewitt 1972, p. 9) and consists of thin- to massive-bedded, medium- to fine-grained quartzose sandstone. The formation is suitable for building stone and has been quarried at several places along the Niagara Escarpment, especially in the Town of Caledon. No areas suitable for quarry development exist in the Regional Municipality of Hamilton-Wentworth. The Whirlpool Formation is overlain by shales and limestones of several other formations of the Clinton and Cataract Groups, none of which are well suited for the production of load-bearing aggregate. There is no history of extraction of these remaining formations in the region.

The Clinton and Cataract Groups are overlain by dense, erosion-resistant dolostone which forms the brow of the Niagara Escarpment and underlies much of the Flamborough, Norfolk and Haldimand plains. At the time these rocks were laid down, considerable differences in the depositional environment existed in various parts of the region. As a result, the formation is lithologically diverse and has been given two different names in the northern and southern sections of the region. North of the Clappisons Corners - Waterdown area the rock consists of massive-bedded, medium- to coarse-crystalline dolostone and is known as the Amabel Formation. To the south of this region, including the northern edge of the Township of Glanbrook, much of the Town of Stoney Creek and a small area in the Town of Ancaster, the rock is named the Lockport Formation (Liberty, Bond and Telford 1976; Liberty, Feenstra and Telford 1976). The Lockport is lithologically more diverse than the Amabel Formation to which it is time equivalent, and so the Lockport has been divided into three members. The lower two members -the Goat Island and Gasport Members - occur only in the Niagara Peninsula. The uppermost member - the Eramosa Member - occurs in the south but also is recognized as forming the upper part of the Amabel Formation north of Dundas.

The Lockport Formation underlies most of the Town of Stoney Creek south of the Niagara Escarpment. Drift thickness is generally less than 25 feet (8 m) except in the area of the Vinemount Moraine. North of the road between concessions 5 and 6, the lower two members of the formation occur. The Gasport Member is exposed at the Escarpment brow. It consists of fine-crystalline, medium- to massive-bedded porous dolostone. It ranges in thickness from less than 2 feet (0.6 m) near Fruitland to a maximum of 21 feet (6 m) (Liberty, Feenstra and Telford 1976). The Gasport Member is not exposed in either of the two licenced quarries in the Town of Stoney Creek.

The Goat Island and Eramosa Members of the Lockport Formation are well exposed in the Vinemount Quarries of Armbro Materials Limited (quarry no. Q6). A 40- to 85-foot (12 to 26 m) face in the quarry exposes approximately 50 feet (15 m) of the Goat Island Member at the base of the face. The member consists of very fine crystalline, medium-bedded dolostone. An eight-foot (2 m) section of this material contains abundant chert nodules and is named the "Ancaster chert beds" (Hewitt 1960, p. 102). These beds are unsuitable for many aggregate products. The upper 30 feet (9 m) of the Vinemount quarry section expose the Eramosa Member. The lower 17 feet (5 m) of this member consist of fine-crystalline dolostone with abundant shaly partings. These beds are characterized by rapid weathering and poor resistance to erosion.

The shaly beds are known as the "Vinemount shale beds" (Hewitt 1960, p. 102) (also referred to as the "unnamed member" by Liberty, Feenstra and Telford 1976). The shale beds have a thickness of up to 17 feet (5 m) in this area (Hewitt 1971). The poor soundness of this material makes it unsuitable for the production of load-bearing aggregate and so these beds must be avoided. The Vinemount shale beds also occur in the quarries licenced to Taro Properties Limited in the western part of the Town of Stoney Creek (quarry nos. Q7, Q8 and Q9). The faces in the Taro Properties quarries consist of thin-bedded, dark brown, very fine crystalline dolostone of the Eramosa Member. This member may be up to 25 or 30 feet (8 or 9 m) thick and often forms a small scarp south of the main Niagara Escarpment, as can be seen just to the north of the Vinemount Quarries. The Eramosa Member has been mapped separately on Map 3 because it is a very distinct unit and more widespread than the other two members of the Lockport.

In general all three members of the Lockport Formation are suitable for use as aggregate, with the exception of the Ancaster chert beds and Vinemount shale beds, as outlined above. In addition to road aggregate, the Eramosa Member has been extracted at quarry no. 1 for use as railway ballast, agricultural lime, fluxstone and for the production of dead-burned dolomite (Vos 1969, p. 22).

In summary, after accounting for the undesirable Ancaster chert beds and the Vinemount shale beds, approximately 50 feet (15 m) of good quality stone are available for extraction in the Lockport Formation in the Town of Stoney Creek. All of the area of subcrop of the Eramosa Member covered by less than 25 feet (8 m) of drift in the Town of Stoney Creek has been selected for possible resource protection. The area of subcrop occupied by the Goat Island and Gasport Members has not been selected because of the general thinness and variability of the members in this area.

The Amabel Formation occurs north of the Clappisons Corners - Waterdown area. The Amabel Formation underlies the eastern half of the Township of Flamborough. The formation consists of a lower, undivided unit which is the lateral facies equivalent of the Gasport and Goat Island Members of the Lockport Formation. This unit underlies the geographic township of East Flamborough, and consists of massive-bedded, medium- to coarse-crystalline dolostone with abundant reefal structures. Approximately 30 feet (9 m) of this unit of the Amabel Formation are exposed at the face of the Niagara Escarpment, and further to the west, the unit thickens rapidly (Liberty, Bond and Telford 1976). It has been extracted at several quarries to the northeast of the region. Drift cover over the unit is less than 25 feet (8 m) in several parts of the Township of Flamborough and all such areas have been selected for possible resource protection.

The Eramosa Member forms the upper part of the Amabel Formation in the Township of Flamborough and extends as far north as Guelph (Liberty, Bond and Telford 1976). The Eramosa consists of thin-bedded, fine-crystalline, dark brown dolostone with bituminous or shaly partings much the same as that found in the Town of Stoney Creek. Approximately 36 feet (11 m) of the Eramosa Member are exposed in the Dundas Quarry of Canada Crushed Stone Limited (quarry no. 1). The stone is used for a wide variety of high quality crushed products for road building and residential construction. Drift cover over the Eramosa Member is less than 25 feet (8 m) throughout much of its area of occurrence and most of the area has been selected for possible resource protection. Vos (1969, p. 22) notes that lateral lithological variations in the Eramosa may prevent its use in some areas. While most of the Eramosa in the region has been selected for possible protection,

thorough testing of sites before development will reveal the best areas for extraction.

The Guelph Formation overlies the Amabel Formation, occurring beneath thin drift in the western third of the Township of Flamborough and under considerable thicknesses of lacustrine sediments in the Town of Ancaster and the Township of Glanbrook. The Guelph Formation consists of massive-bedded, fine- to medium-crystalline dolostone. Some beds contain abundant fossils so that the rock weathers irregularly (Liberty, Bond and Telford 1976). The rock has high chemical purity and is a valuable raw material for numerous metallurgical products. The Guelph Formation is extracted on a large scale at the Canada Crushed Stone quarries (quarry no. 1) for a variety of products as well as the Guelph quarry of Guelph Dolime for the production of lime used in building supplies. The rock is generally relatively soft and is not well suited for the production of load-bearing aggregate in most areas. However, it has been extracted for this use at several quarries in southern Ontario. The entire extent of the Guelph Formation in the western part of the Township of Flamborough where drift cover is less than 25 feet (8 m) has been selected for possible resource protection. Similarly, an extensive area of the Guelph Formation in the northern part of the Township of Glanbrook has also been selected for possible resource protection.

The Guelph Formation is overlain at the southern edge of the Township of Glanbrook by shale and evaporitic deposits of the Salina Formation. The Salina is the youngest of the bedrock units in the regional municipality. It has been extracted elsewhere in southern Ontario for gypsum (Hewitt 1960) but has little value as a source of crushed stone for load-bearing aggregate. In the Township of Glanbrook drift cover over the Salina is greater than 25 feet (8 m), therefore no areas have been selected for possible resource protection.

EXTRACTIVE ACTIVITY FOR CRUSHED STONE IN THE REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

Quarrying has taken place in all parts of the regional municipality, with the exception of the Town of Ancaster. A total of ten quarries have been located on Map 3 and described in Table 5. Most of the sources are developed in the Guelph, Lockport and Amabel Formations. Some of the quarries have been inactive since the designation of the regional municipality under The Pits and Quarries Control Act, 1971. At the writing of this report, a total of eight quarries were licenced for operation in the regional municipality. Four licenced operations quarry the Eramosa Member of the Lockport Formation in the Town of Stoney Creek. The remaining four licenced quarries make use of the Guelph Formation and underlying Lockport or Amabel Formations in the Township of Flamborough.

The total area licenced for extraction in the eight licenced quarry properties is 1513.0 acres (612.3 ha). The tonnage of crushed stone removed from the licenced sources has been tabulated on an annual basis by the Cambridge District Office of the Ontario Ministry of Natural Resources. From 1976 to 1980 the average annual production was approximately 2.8 million tons (2.5 million tonnes). Production trends are not readily apparent over such a short period of time but it is likely that the average production throughout Ontario will increase in the near future (Jewett 1977).

SELECTED BEDROCK RESOURCE AREAS IN THE TOWNSHIP OF FLAMBOROUGH

Four large areas of bedrock of the Amabel and Guelph Formations covered by thin drift have been selected for possible resource protection in the Township of Flamborough. These selected areas contain very large possible resources of good quality stone suitable for road building, construction, and for a variety of metallurgical products. Considerable latitude exists in the identification of specific locations for possible extractive development within the Resource Areas and it is not expected that the entire extent of the Areas be designated in an official plan.

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 consists of the entire extent of the Amabel Formation covered by less than 25 feet (8 m) of drift in the eastern part of the township. The Resource Area is divided into two segments; one lying around and to the north of Carlisle, and the second lying at the southern boundary of the township, near Waterdown. The two segments of the Area are separated by thick drift which forms part of the Waterdown Moraines. The northernmost of

the two areas lies in the Flamborough Plain. Overburden is generally less than 15 feet (5 m) as shown by numerous water wells, except in areas where drumlins occur. The overburden consists of Wentworth Till. The southern of the two segments is overlain by less than 15 feet (5 m) of Halton Till.

One quarry (quarry no. Q5) has been opened in the Resource Area near Waterdown. The quarry exposures are the most northern occurrence of the Lockport Formation lithologies. The remainder of the Resource Area north of the quarry, however, is composed of the Amabel Formation. The northern portions of Resource Area 1 consist of the well developed massive reefal facies of the Amabel Formation.

Selected Resource Area 1 occupies a total of 16,700 acres (6800 ha). Much of the southern portion of the Resource Area is unavailable for extraction because of residential and other development surrounding the settlements of Clappison's Corners and Waterdown. In addition, parts of the southern area lie within the "Parkway Belt West" and the "Niagara Escarpment" policy areas identified in the Official Plan for the regional municipality (Regional Municipality of Hamilton-Wentworth 1980). In the northern portion of Resource Area 1 some land south of Carlisle and Flamboro Station will be unavailable for quarrying due to residential development. It is estimated that approximately 14,900 acres (6000 ha) are presently available for extraction in the entire Resource Area. Assuming an average thickness of usable material of 60 feet (18 m), total resources of crushed stone are estimated to be 3200 million tons (2900 million tonnes). Access to the Resource Area is provided by a well developed road grid and by a line of the Canadian Pacific Railway. The Area forms part of a large possible resource area that extends to the east into the Regional Municipality of Halton and forms a potential aggregate source of provincial significance.

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 consists of the entire extent of the Eramosa Member covered by less than 25 feet (8 m) of drift. This area forms a band 1 to 2 miles (2 to 3 km) wide trending north to south in the eastern portion of the township. As with Resource Area 1, Resource Area 2 consists of two segments; one in the north and a much smaller area in the south. The two segments are separated by a region of thicker drift which corresponds to part of the Waterdown Moraines. In the north, drift is generally less than 20 feet (6 m) and bedrock exposures are common. In the south much of the potential area lies within the Parkway Belt West and Niagara Escarpment policy areas and may not be available for extraction. In addition, considerable residential and other development in this area reduce the potential for quarrying.

The two segments that make up Resource Area 2 occupy a total of 11,000 acres (4450 ha). As mentioned previously, much of the southern part of the Resource Area may be unavailable for extraction. In the north, population densities are low, and competing land uses are not as restrictive. Some land in the vicinity of the settlements of Freelton, Strabane and Harper Corner will be unavailable, however. It is estimated that approximately 9800 acres (4000 ha) in Area 2 are presently available for extraction. Assuming an average workable thickness of 50 feet (15 m) throughout the Resource Area, resources of crushed stone are estimated to be 1760 million tons (1600 million tonnes). Parts of the workable thickness of 50 feet (15 m) will contain the Amabel Formation which underlies the Eramosa.

Access to the Area is provided by several paved roads but there is no direct rail access. Quarries might be established in several parts of the Resource Area and, as in Area 1, the most attractive sites for possible development may be in the northern section, northwest of Strabane and west of Harper Corner.

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 consists of a band of the Guelph Formation roughly 1.5 miles (2.4 km) wide trending north-south through the central portion of the township. The eastern boundary of the Resource Area is defined by the contact between the Eramosa Member and the overlying Guelph Formation. The western boundary is defined by an interpretive boundary which represents the point at which the thickness of the Guelph Formation begins to exceed 30 feet (9 m). In this Area, the Eramosa Member is the preferred quarrying material because of its superior load-bearing and wear characteristics in comparison to the Guelph Formation which is generally unsuitable for

many high-specification aggregate uses. At the old quarry of Canada Crushed Stone located south of King's Highway 5 for example, only the upper 6 feet (2 m) of the face are Guelph Formation, the rest (consisting of more than 40 feet (12 m)) is the Eramosa Member. The Guelph Formation is extracted to produce lime and metallurgical products. The underlying Eramosa Member is quarried for road-building and construction aggregate. Quarrying through the Guelph Formation to the Eramosa Member and thus being able to supply two types of bedrock from one quarry is possible in the other properties in the vicinity of Hayesland (quarry nos. Q1, Q2, and Q3).

Drift thickness over the bedrock in the Resource Area is generally less than 20 feet (6 m), and in the area immediately to the west of the Canada Crushed Stone quarry, on concessions 3, 4 and 5 of the geographic townships of West Flamborough and Beverly, surface exposures are common. In the northern part of Resource Area 3, numerous drumlins overlie the bedrock surface and to the north of concession 6 there are extensive wetland areas of the Beverly swamp covering the bedrock. These parts of the Resource Area are much less favourable extractive sites than the area to the west of Hayesland. Vos (1969) also identified parts of Resource Area 3 as an area of potential interest for quarrying.

Selected Bedrock Resource Area 3 occupies a total of 12,900 acres (5200 ha), exclusive of licenced areas. Of this total, 1750 acres (710 ha) are estimated to have been previously extracted (at the old quarries of Canada Crushed Stone south of Highway 5) or are unavailable due to the presence of roads, houses and other cultural features. Thus, 11,100 acres (4500 ha) are presently available for extraction. As mentioned, the land in the area of the Beverly swamp may not be favourable for quarrying, further reducing the land available for extraction. An average workable thickness of 60 feet (18 m) is assumed throughout Resource Area 3. This figure represents approximately equal proportions of the Guelph Formation and the Eramosa Member. Presently available resources of crushed stone for road building and lime for chemical and metallurgical uses are thus estimated to be 1200 million tons (1090 million tonnes) for each respective use. The areas most attractive for future development are to the immediate north and west of Hayesland.

SELECTED BEDROCK RESOURCE AREA 4

Selected Bedrock Area 4 consists of the very large area of the Guelph Formation, covered by thin drift, in the western portion of the Township of Flamborough. The area of thin drift corresponds closely to the location of the Flamborough Plain in Figure 2. The western and northern extensions of the Area into the townships of North and South Dumfries, and Puslinch, respectively, have also been selected for possible resource protection. Most of the drift over the bedrock consists of a veneer of Wentworth Till, generally less than 15 feet (5 m) thick. Bedrock exposures are common and the only areas of thick drift occur where drumlins have been formed on the till plain.

A licenced quarry (quarry no. Q4) has been opened to the west of Rockton. Vos (1969, p. 39) notes that a 12-foot (4 m) face in the quarry exposes thin-bedded, fine-crystalline Guelph dolostone. Some shaly partings in the rock further reduce the wearing capability of the rock but it has been used for road-building aggregate. With respect to the general quality of the Guelph Formation in the Area, Vos (1969, p. 40) notes: "Although production of road metal has taken place in several areas of Beverly Township careful testing must be carried out before the choice of a quarry site is made. Guelph dolomite is frequently too soft for use as aggregate." Drilling records for several localities in the Resource Area indicate thicknesses of the Guelph Formation in excess of 250 to 300 feet (76 to 91 m) (Vos 1969).

Selected Bedrock Resource Area 4 occupies a total of 27,500 acres (11 100 ha). The Area is sparsely populated and competing land uses are minor. Areas where quarrying may not be possible are in the vicinity of the settlements of Rockton, Sheffield and Kirkwall. Some poorly drained land to the east of Kirkwall may also be unattractive for extraction because of the high water table. The presently available portions of Resource Area 4 occupy 24,400 acres (9900 ha) and, assuming a workable thickness of 60 feet (18 m) throughout the deposit, presently available resources of stone suitable for lime production are estimated to be 5300 million tons (4800 million tonnes).

It should be noted that although large areas of the Guelph Formation are available for extraction, this material is not best suited for the

production of load-bearing aggregate. The stone contained in Resource Areas 1, 2 and 3 is superior and should be given primary consideration in the selection of specific areas for resource protection. The Guelph Formation bedrock in Area 4 is best suited for production of chemical and metallurgical lime. Demand for these products is very low compared to demand for road and construction aggregate.

SELECTED BEDROCK RESOURCE AREAS IN THE TOWN OF ANCASTER

Although most of the bedrock formations described in the bedrock geology section occur in the Town of Ancaster, the thickness of surficial sediments overlying the bedrock is generally too great to permit quarrying. A small area of thin drift occurs in the northeastern portion of the town and a small part of the Niagara Escarpment is exposed on the south side of Ancaster Creek. Stone of the Guelph and Lockport Formations is near the surface in these areas but extensive residential and industrial development prohibit quarrying. For these reasons no areas have been selected for possible resource protection in the Town of Ancaster.

SELECTED BEDROCK RESOURCE AREAS IN THE TOWN OF STONEY CREEK

SELECTED BEDROCK RESOURCE AREA 5

A wide band of the Eramosa Member of the Lockport Formation covered by thin drift has been selected for possible resource protection. The Area trends east-west across the central portion of the town. It is defined on its northern boundary by the low scarp formed by the appearance of the Eramosa Member and is defined on the south by the 25-foot (8 m) drift thickness contour line. Four licenced quarries are developed in the Resource Area along its northern edge (quarry nos. Q6, Q7, Q8, and Q9). The quarries expose the Lockport Formation and all expose parts of the Vinemount shale beds (Hewitt 1960). The Ancaster chert beds are also exposed in the Armbro Materials Limited Vinemount Quarry (Quarry no. Q6). These beds are not suitable for the production of most load-bearing aggregate, so they must be avoided during extraction. A wide range of different-sized crushed products is made at the quarries. The aggregate is used primarily in road construction, but is also suited for asphalt and concrete aggregate (Hewitt 1960, p. 105).

The Resource Area (including two small areas covered by thin drift at the southern boundary of the town which are the northern extensions of Selected Bedrock Resource Area 6 in the Township of Glanbrook) occupies a total of 7100 acres (2850 ha). Land use in the Area is predominantly agricultural although three small settlements, Elfrida, Tapleytown and Tweedside are located in the Resource Area. Approximately 1550 acres (630 ha) have been made unavailable for extraction by these settlements and associated roads, leaving 5500 acres (2230 ha) presently available. Assuming an average thickness of usable material of 50 feet (15 m) throughout Resource Area 5, presently available resources of good quality crushed stone are estimated to be 990 million tons (900 million tonnes). The workable thickness includes approximately 20 feet (6 m) of the underlying Goat Island and Gasport Members of the Lockport Formation. Quarries may be established in numerous locations throughout the Resource Area. Access is provided by a well developed grid of roads and by a line of the Toronto, Hamilton and Buffalo Railway.

SELECTED BEDROCK RESOURCE AREAS IN THE TOWNSHIP OF GLANBROOK

Two small areas of the Eramosa Member of the Lockport Formation and one extensive area of the Guelph Formation have been selected for possible resource protection in the Township of Glanbrook.

SELECTED BEDROCK RESOURCE AREA 6

Selected Bedrock Resource Area 6 contains bedrock of the Eramosa Member of the Lockport Formation and comprises two areas which are located at the northeastern corner and near the north-central boundary of the township. Drift cover, which consists of lacustrine deep water sediments and Halton Till, is less than 25 feet (8 m) throughout the Resource Area. Both sections of the Area are southern extensions of the large area of the Eramosa Member selected for protection in the Town of Stoney Creek.

A small quarry (quarry no. Q10) is located immediately west of Area 6 beside the Canadian National Railways line. The quarry face exposes 4 feet (1.2 m) of Guelph Formation overlying more than 9 feet (3 m) of the Eramosa Member. The aggregate was used for road building and

railway ballast.

Resource Area 6 occupies a total of 2080 acres (840 ha), of which 1530 acres (620 ha) are presently available for extraction. Assuming a workable thickness of 50 feet (15 m) throughout the Resource Area, crushed stone resources are estimated to be 275 million tons (250 million tonnes). As in Stoney Creek, the workable thickness of 50 feet (15 m) is composed of approximately 30 feet (9 m) of the Eramosa Member, underlain by 20 feet (6 m) of the Goat Island and Gasport Members of the Lockport Formation.

SELECTED BEDROCK RESOURCE AREA 7

Selected Bedrock Resource Area 7 consists of an extensive area of the Guelph Formation, covered by less than 25 feet (8 m) of drift, located in the north-central part of the township. Part of the area of thin drift is associated with the valley of Twenty Mile Creek. The Resource Area corresponds to an area of potential interest for quarrying identified by Vos (1969). No quarries have been developed in the Resource Area, but the material is likely very similar to the Guelph Formation found throughout the region. Since the Resource Area is located near the contact of the Guelph Formation with the underlying Lockport Formation, it is likely that the Guelph is thin enough to permit the extraction of the underlying higher quality Eramosa Member of the Lockport Formation. Assuming an average dip of the bedrock formations of 30 feet per mile (6 m per kilometre) (Vos 1969, p. 31) it is probable that the Guelph Formation is less than 45 feet (14 m) thick throughout Resource Area 7 and that consequently 15 to 45 feet (5 to 14 m) of the Eramosa Member would also be available for extraction. Thus the workable thickness for Resource Area 7 has been estimated at 60 feet (18 m) but includes approximately 30 feet (9 m) of each of the Guelph and Eramosa.

Resource Area 7 has a total area of 4300 acres (1740 ha), most of which is presently available because of the relatively low level of residential development in the Area. Based on the area and thickness estimates, the presently available resources of crushed stone in Resource Area 7 are approximately 760 million tons (690 million tonnes). As in Selected Bedrock Resource Area 6, the overburden in Resource Area 7 consists of lacustrine sand and silt and glacial till, which pose few stripping problems. Numerous water wells in the area indicate that the drift is from 15 to 25 feet (5 to 8 m) thick. Access to the Resource Area is provided by several gravel-surfaced and paved roads and by a railway line.

SUMMARY

The only large sand and gravel deposits in the Regional Municipality of Hamilton-Wentworth are located in the Township of Flamborough and the Town of Ancaster. Four areas have been selected for possible resource protection at the primary level. These resource areas contain total possible resources of 130 million tons (118 million tonnes) of sand and gravel suitable for a range of road-building and construction aggregate. The amount of crushable aggregate is low in most of the resource areas and the quality of the stone is poor. In some areas, the presence of excess silt and clay and cementation further limit possible uses of some of the aggregate.

The region has very large possible resources of stone from the Lockport and Amabel Formations which are suitable for the production of a wide range of road-building and construction aggregate. Very large resources of stone are also available from the Guelph Formation which is suitable for chemical and metallurgical products as well as some load-bearing aggregate. Five areas of the Lockport and Amabel Formations (including the Eramosa Member) have been selected for possible resource protection. These Areas have total possible crushed stone resources of 7800 million tons (7100 million tonnes). Two areas of the Guelph Formation have also been selected, having possible lime resources of 6900 million tons (6300 million tonnes).

The bedrock resource areas constitute a resource of provincial importance and care should be taken to ensure the continuing availability of sufficient material for future needs. Because of the very extensive nature of the selected resource areas and the general uniformity of the stone quality throughout the areas, considerable latitude in the actual identification of portions of the areas for resource protection is possible. It is not intended that all of the Resource Areas shown on Map 3 be protected.

It is important to note that the availability of possible resources in the Selected Sand and Gravel and Selected Bedrock Resource Areas

may be constrained by designations set through the Niagara Escarpment Plan.

Enquiries regarding the Aggregate Resources Inventory of the Regional Municipality of Hamilton-Wentworth should be directed to the Ontario Ministry of Natural Resources either at the Cambridge District Office, Box 2186, Beaverdale Road, Cambridge, Ontario, N3C 2W1 (Tel. (519) 658-9356) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWNSHIP OF FLAMBOROUGH			
1	G-IC	60 (24)	3 (3)
	S-IC	20 (8)	1 (1)
	G-K	115 (46)	6 (5)
	S-LP	15,700 (6400)	780 (710)
	G-OW	790 (320)	40 (36)
	S-OW	60 (24)	3 (3)
2	G-E	510 (206)	19 (17)
	G-K	45 (12)	2 (2)
	S-K	3300 (1340)	124 (112)
	S-LP	23,300 (9400)	870 (790)
	G-OW	1870 (760)	70 (64)
3	G-E	190 (77)	3 (3)
	S-LP	1120 (455)	22 (20)
4	S-LP	470 (190)	5 (4)
	G-OW	145 (59)	1 (1)
		47,500 (19 200)	1950 (1770)

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWN OF ANCASTER			
1	S-LP	11,600 (4700)	585 (530)
	S-OW	190 (77)	10 (9)
2	S-LP	150 (61)	6 (5)
3	S-AL	60 (24)	1 (1)
	S-IC	10 (4)	<1 (<1)
		12,000 (4850)	600 (540)
TOWN OF STONEY CREEK			
3	S-AL	50 (20)	1 (1)
	S-LP	150 (61)	3 (3)
4	G-LB	15 (6)	<1 (<1)
		215 (87)	4 (4)
TOWNSHIP OF GLANBROOK			
3	S-AL	3400 (1380)	68 (62)

N.B. Minor variations in all tables are due to rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, REG. MUN. OF HAMILTON-WENTWORTH

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
TOWNSHIP OF FLAMBOROUGH							
LICENCED PITS							
1	G1-24	Jonben Enterprises Limited	8	7	100.0 (40.5)	12-15 (4-5)	0-30
2	H3-51	D. Coverdale	2	8	21.2 (8.6)	20 (6)	40
3	H3-62	J & R Posavad	3	8	20.8 (8.4)	5-15 (2-5)	35
4	G1-275	Tibbits Bulldozing Limited	11	10	15.6 (6.3)	20 (6)	35
5	–	Oaklands Properties Burlington Limited	8	6	25.5 (10.3)	15 (5)	35
					183.1 (74.1)		
UNLICENCED PITS*							
6	–	Tibbits Bulldozing Limited	10	10		15 (5)	35
7	G1-23	Standard Industries Limited	6 & 7	6		10 (3)	35
8	G1-223	Rutherford	9	6		10 (3)	0-30
9	G1-231	Stanek	6	8		10 (3)	0-30
10	G1-124	G. Wright	2	10		8 (2)	10-45
11	H3-21	Tibbits Bulldozing Limited	7	9		10-15 (3-5)	Depleted
12	H3-36	J. Gibson	1	8		10-15 (3-15)	Overgrown
13	G1-42	Beverly	8	9		15 (5)	45

TABLE 2 | SAND AND GRAVEL PITS, REG. MUN. OF HAMILTON-WENTWORTH

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
TOWNSHIP OF FLAMBOROUGH							
14	G1-279	P. Wilson	12	9		20-25 (6-8)	30-40
15	G1-54	I. Anderson	6	8		20 (6)	40
16	G1-29	K. Evans	11	11		10 (3)	
17	G1-40	Myers	3	10		10-20 (3-6)	0-35
18	G1-246	H. Huffman	21	10		20-30 (6-9)	5-50
19	G1-43	Plummer	20	10		20 (6)	20-50
20	G1-170	F. Simons	13	6		Below Groundwater	10-35
21	G1-47	Stanko and MacIntosh	7	7		5-10 (2-3)	10
TOWN OF ANCASTER							
LICENCED PITS							
22	B13-54	Wm. Smith & Son Ltd.	36	2	193.0 (78.1)	15-20 (5-6)	sand
23	G8-33	A. & G. Fair Excavation Ltd.	42	4	47.8 (19.3)	20 (6)	sand
24	G8-27	D. Shaver	45	3	20.0 (8.1)	15 (5)	sand
					260.8 (105.6)		
UNLICENCED PITS*							
25	B13-50	J. Greene	34	2	–	7 (2)	0-25
26	–	Whaley	45	3	–	15-20 (5-6)	sand

TABLE 2 | SAND AND GRAVEL PITS, REG. MUN. OF HAMILTON-WENTWORTH

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
TOWN OF STONEY CREEK							
		– NONE –					
TOWNSHIP OF GLANBROOK							
		– NONE –					

* Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3 SELECTED SAND AND GRAVEL RESOURCE AREAS, REG. MUN. OF HAMILTON-WENTWORTH

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
TOWNSHIP OF FLAMBOROUGH						
1	1490 (600)	385 (156)	85 (34)	1020 (415)	15 (5)	38 (34)
2	3450 (1400)	1630 (660)	20 (8)	1800 (730)	15 (5)	68 (62)
3	530 (214)	40 (16)	0 (0)	490 (198)	20 (6)	18 (16)
	5500 (2230)	2060 (830)	105 (42)	3300 (1340)		124 (112)
TOWN OF ANCASTER						
4	140 (57)	20 (8)	10 (4)	110 (44)	20 (6)	6 (5)
	5600 (2270)	2080 (840)	115 (46)	3400 (1380)		130 (118)
TOWN OF STONEY CREEK						
			– NONE –			
TOWNSHIP OF GLANBROOK						
			– NONE –			

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWNSHIP OF FLAMBOROUGH				
0-3 (0-1)	Guelph	60 (18)	6500 (2650)	1400 (1270)
3-25 (1-8)	Guelph	60 (18)	34,500 (14 000)	7500 (6800)
25-50 (8-15)	Guelph	60 (18)	14,800 (6000)	3200 (2900)
			56,000 (22 700)	12,100 (11 000)
0-3 (0-1)	Amabel (Eramosa Member)	50 (15)	1280 (520)	230 (209)
3-25 (1-8)	Amabel (Eramosa Member)	50 (15)	9700 (3950)	1750 (1590)
25-50 (8-15)	Amabel (Eramosa Member)	50 (15)	2900 (1170)	520 (470)
			13,900 (5600)	2500 (2270)
0-3 (0-1)	Amabel	60 (18)	40 (16)	9 (8)
3-25 (1-8)	Amabel	60 (18)	16,700 (6800)	3600 (3250)
25-50 (8-15)	Amabel	60 (18)	8800 (3550)	1900 (1720)
			25,500 (10 300)	5500 (5000)
0-3 (0-1)	Clinton & Cataract Groups	25 (8)	300 (121)	24 (22)
3-25 (1-8)	Clinton & Cataract Groups	25 (8)	200 (81)	16 (14)
			500 (202)	40 (36)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWNSHIP OF FLAMBOROUGH				
0-3 (0-1)	Queenston	60 (18)	25 (10)	5 (4)
3-25 (1-8)	Queenston	60 (18)	90 (36)	17 (15)
25-50 (8-15)	Queenston	60 (18)	30 (12)	6 (5)
			145 (59)	28 (25)
			96,000 (39 000)	20,200 (18 300)
TOWN OF ANCASTER				
25-50 (8-15)	Guelph	30 (9)	1070 (435)	116 (105)
3-25 (1-8)	Lockport (Eramosa Member)	30 (9)	40 (16)	4 (4)
25-50 (8-15)	Lockport (Eramosa Member)	30 (9)	920 (370)	99 (90)
			960 (388)	103 (93)
3-25 (1-8)	Lockport (Gasport and Goat Island Members)	20 (6)	350 (142)	25 (23)
25-50 (8-15)	Lockport (Gasport and Goat Island Members)	20 (6)	730 (295)	53 (48)
			1080 (435)	78 (71)
0-3 (0-1)	Clinton & Cataract Groups	25 (8)	50 (20)	4 (4)
3-25 (1-8)	Clinton & Cataract Groups	25 (8)	40 (16)	4 (4)
			90 (36)	8 (7)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWN OF ANCASTER				
3-25 (1-8)	Queenston	60 (18)	150 (61)	29 (26)
25-50 (8-15)	Queenston	60 (18)	145 (59)	28 (25)
			295 (119)	57 (52)
			3500 (1420)	246 (223)
TOWN OF STONEY CREEK				
0-3 (0-1)	Lockport (Eramosa Member)	30 (9)	390 (158)	42 (38)
3-25 (1-8)	Lockport (Eramosa Member)	30 (9)	7000 (2850)	760 (690)
25-50 (8-15)	Lockport (Eramosa Member)	30 (9)	3050 (1230)	330 (300)
			10,400 (4200)	1130 (1030)
0-3 (0-1)	Lockport (Gasport and Goat Island Members)	20 (6)	2000 (810)	144 (131)
3-25 (1-8)	Lockport (Gasport and Goat Island Members)	20 (6)	2460 (1000)	177 (161)
25-50 (8-15)	Lockport (Gasport and Goat Island Members)	20 (6)	1100 (445)	79 (72)
			5600 (2270)	400 (365)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWN OF STONEY CREEK				
0-3 (0-1)	Clinton and Cataract Groups	25 (8)	360 (146)	32 (29)
3-25 (1-8)	Clinton and Cataract Groups	25 (8)	90 (36)	8 (7)
			450 (182)	40 (36)
0-3 (0-1)	Queenston	60 (18)	2600 (1050)	500 (455)
3-25 (1-8)	Queenston	60 (18)	1670 (680)	320 (290)
25-50 (8-15)	Queenston	60 (18)	2220 (900)	425 (385)
			6500 (2650)	1240 (1120)
			23,000 (9300)	2800 (2550)
TOWNSHIP OF GLANBROOK				
25-50 (8-15)	Salina	60 (18)	80 (32)	17 (15)
3-25 (1-8)	Guelph	30 (9)	5000 (2020)	540 (490)
25-50 (8-15)	Guelph	30 (9)	6700 (2700)	720 (650)
25-50 (8-15)	Guelph	60 (18)	5800 (5300)	1250 (1130)
			17,500 (7100)	2500 (2270)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, REG. MUN. OF HAMILTON-WENTWORTH

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
TOWNSHIP OF GLANBROOK				
3-25 (1-8)	Lockport (Eramosa Member)	30 (9)	2080 (840)	225 (204)
25-50 (8-15)	Lockport (Eramosa Member)	30 (9)	1600 (650)	173 (157)
			3700 (1500)	400 (365)
			21,300 (8600)	2900 (2650)

TABLE 5 | QUARRIES, REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
TOWNSHIP OF FLAMBOROUGH						
LICENCED QUARRIES						
Q1	H3-2	Canada Crushed Stone Division of Steetley Industries Limited	9, 10, 11 & 12 7, 8 & 9	3 4	977.0 (395.4)	48 (15)
Q2	G1-26	Flamborough Quarries Limited	5 & 6	4	102.0 (41.3)	22 (7)
Q3	–	Steetley Industries Limited	10	4	48.4 (19.6)	
Q4	–	Township of Flamborough	18	4	7.4 (3.0)	12 (4)
					1134.8 (459.2)	
UNLICENCED QUARRIES*						
Q5	H3-28	Armbro Construction & Materials Ltd.	12	3	–	35 (11)
TOWN OF ANCASTER						
			– NONE –			
TOWN OF STONEY CREEK						
LICENCED QUARRIES						
Q6	G8-11	Armbro Materials Limited	5	5	50.0 (20.2)	40-85 (12-26)
Q7	G8-2	Taro Properties Limited	27, 28	6	178.1 (72.1)	15
Q8	G8-2	Taro Properties Limited	25, 26	6	121.2 (49.0)	20 (6)
Q9	G8-2	Taro Properties Limited	26	6	28.9 (11.7)	20 (6)
					378.2 (153.1)	

TABLE 5 | QUARRIES, REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
TOWNSHIP OF GLANBROOK						
UNLICENCED QUARRIES*						
Q10	–	Unknown	14	1	–	5-15 (2-5)

* Abandoned quarries or wayside quarries operating under authority of a permit.

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, REG. MUN. OF HAMILTON-WENTWORTH

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
TOWNSHIP OF FLAMBOROUGH							
1	3-25 (1-8)	16,700 (6800)	1780 (720)	20 (8)	14,900 (6000)	60 (18)	3200 (2900)
2	3-25 (1-8)	11,000 (4450)	1200 (485)	20 (8)	9800 (4000)	50 (15)	1760 (1600)
3	0-25 (0-8)	12,900 (5200)	1600 (650)	150 (61)	11,100 (4500)	60* (18)	2400 (2180)
4	0-25 (0-8)	27,500 (11 100)	3100 (1250)	0 (0)	24,400 (9900)	60 (18)	5300 (4800)
		68,000 (27 500)	7700 (3100)	190 (77)	60,000 (24 300)		12,700 (11 500)

* Estimated workable thickness in this Selected Area includes 30 feet (9 m) of the Eramosa Member which underlies the Guelph Formation.

TOWN OF ANCASTER

– NONE –

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, REG. MUN. OF HAMILTON-WENTWORTH

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
TOWN OF STONEY CREEK							
5	0-25 (0-8)	7100 (2850)	1550 (630)	50 (20)	5500 (2230)	50* (15)	990 (900)
TOWNSHIP OF GLANBROOK							
6	3-25 (1-8)	2080 (840)	550 (222)	0 (0)	1530 (620)	50* (15)	275 (250)
7	3-25 (1-8)	4300 (1740)	800 (325)	0 (0)	3500 (1420)	60** (18)	760 (690)
		6400 (2600)	1350 (550)	0 (0)	5000 (2020)		1030 (930)

* Estimated workable thickness in this Selected Area includes 20 feet (6 m) of the Lockport Formation (Gasport and Goat Island members) which underlies the Eramosa Member.

** Estimated workable thickness in this Selected Area includes 30 feet (9 m) of the Eramosa Member which underlies the Guelph Formation.

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APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CAMBRIAN

The first Period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a large rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A Period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DIRT

See fines.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.074 mm). Also described informally as "dirt", these particles are in the silt- and clay-size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder		>-256 mm
Gravel	cobble	64-256 mm
Gravel	pebble	4-64 mm
Gravel	granule	2-4 mm
Sand	coarse	.5-2 mm
	medium	.25-.5 mm
	fine	.074-.25 mm
Silt, clay		<.074 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE)

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early peiod of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago. The Paleozoic Era (or Ancient Life Era) is subdivided into six geologic Periods, of which only four (Cambrian, Ordovician, Silurian, and Devonian) can be recognized in southern Ontario.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE

Estimates of mineral aggregate material based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples of measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SILURIAN

An early Period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Winsconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 7000 to 85 000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain-size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. They vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain-size variability. They are given a qualita-

tive rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. They occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain-size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amount of crushable aggregate in alluvial deposits in low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAIN (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from,

and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS

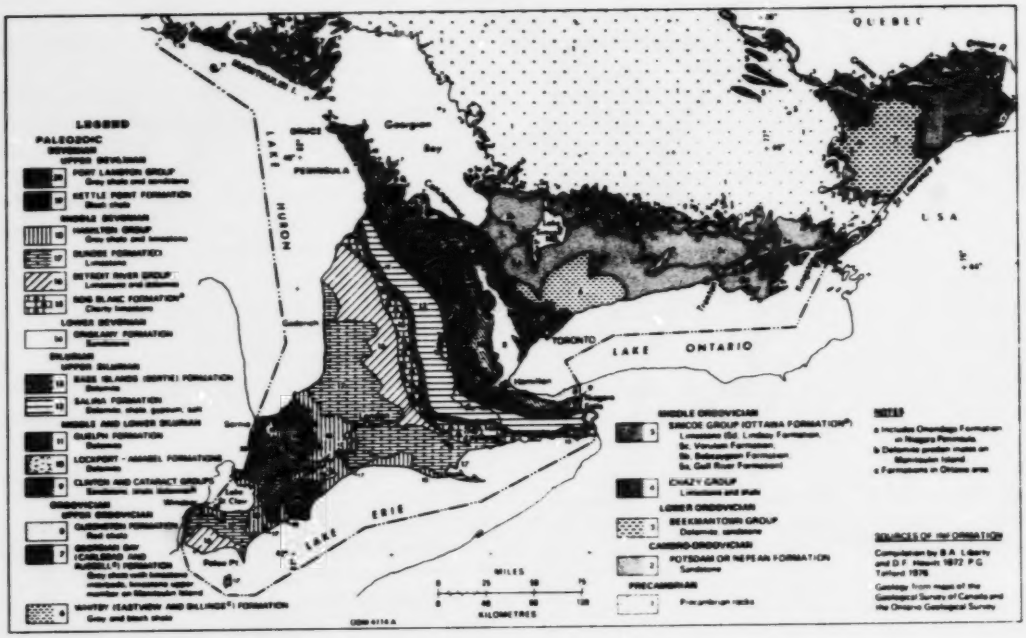

Figure 4 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11-18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion

Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Watertown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, and building stone throughout their area of occurrence, and are a valuable aggregate resource. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliffe Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Falls Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change). Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important

source of high purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas formation is quarried at Amherstburg for crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic- to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. It is quarried at Glen Christie and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular, weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point, Colborne, and Bowmanville for lime. It is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200-300 feet (61-91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for lime. It is unsuitable for crushed stone due to clay impurities and many clayey interbeds, low abrasion resistance. High soundness losses and poor freeze-thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas). Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Five producers in Metro Toronto and Cooksville produce brick and structural tile (Guillet 1967). Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The Group has six formations. Only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are 12 large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa (Guillet 1967). All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto). Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.

MAPS NOT

FILMED

CARTES

OMISES